

METHOD AND APPARATUS FOR PROCESSING INTRA- OR  
POSTOPERATIVE BLOOD LOSS FOR AUTOTRANSFUSION

Field of the Invention

10 The present invention relates to a method of processing  
intra- or postoperative blood loss for autotransfusion, where  
certain cells of the cell suspension to be processed are  
concentrated by centrifugation in a separation unit and then  
5 removed from the separation unit. In addition, the present  
invention concerns an apparatus for carrying out such a method.  
The related art describes various separation devices and the  
respective methods, where blood in particular is separated into  
its components, and the latter, such as red blood cells or  
plasma, are forwarded for further use.

Background of the Invention

15 There are various medical applications for such methods and  
equipment. One of these applications is for intraoperative  
autotransfusion, which has been widely used in recent times.  
Intraoperative autotransfusion is a method which permits  
retransfusion of blood collected from the surgical field. What  
are known as whole-blood transfusion methods, which subject the  
collected blood to particle filtration only, are used in the area  
20 of intraoperative autotransfusion to the point of plasma  
separation/washing methods which supply a washed RBC concentrate  
for reinfusion. The advantages of transfusion of autologous  
blood, i.e., the patient's own blood, in comparison with  
transfusion of homologous blood, i.e., someone else's blood,  
25 include the prevention of infectious diseases such as AIDS and  
hepatitis as well as the prevention of transfusion reactions due  
to biological incompatibility and immune system reactions.

As part of the development of intraoperative autotransfusion  
techniques, it has been found that transfusion of whole blood may  
30 be a disadvantage in comparison with transfusion of washed RBC

concentrates. These disadvantages of the whole blood transfusion methods include the fact that undesirable components of the collected blood cannot be eliminated. Intraoperative blood contains unknown quantities of hemolysis products, foreign constituents infiltrated from the tissue or from external sources, excess volume, anticoagulants, activated plasma and cellular coagulation factors, products of the activation of coagulation and products of the fibrinolytic system. All these components can cause clinical complications, which has led to restrictions on the scope of use. It is known from the related art that blood filtering systems can be used with such autotransfusion systems, but these filters retain only blood clots or pieces of tissue. Such a system is known from U.S. Patent No. 4,014,329. U.S. Patent No. 4,886,487 describes an apparatus for separating excess fluids, but coagulation factors, washing fluid, anticoagulants and other additives are returned with the patient's blood.

As an alternative to whole-blood transfusion, phase separation/washing methods using centrifuges have been developed. Such centrifuges are described in Unexamined German Patent No. 2,262,856 and International Patent WO 89/01792.

German Patent No. 3,817,664 describes a countercurrent extraction centrifuge, in which whole blood is carried in countercurrent with a wash solution. However, neither this apparatus nor this method meets the requirements demanded for autotransfusion, because the unwanted components cannot be separated reliably and effectively.

German Patent No. 4,226,974 C2 describes a method of processing intraoperative blood loss, in which the cell suspension to be processed is passed through a centrifuge line into a separation chamber, where it is broken down into its components according to density. In a second process step, the

concentrated cell fraction, mainly RBC concentrate, is resuspended by continuous addition of a wash solution. Then the remaining noncellular components are subjected to another separation, yielding a high-purity RBC concentrate after removal of the contaminated wash solution. A centrifuge with a separation chamber having an annular channel is used to carry out the process. The annular channel is divided into three zones, with the first separation of the cell suspension taking place in the first zone, resuspension in the second zone and the second separation of the resuspended cells in the third zone.

The above method has proven successful in practice, but it has the disadvantage that relatively large volumes of wash solution must be passed through the centrifuge chamber to displace or dilute the remaining plasma. In view of the large volumes, an isotonic saline solution is generally used as the wash solution in the known method. Because of the relatively large volumes involved, using Ringer's solution, which is tolerated much better by the patient, instead of saline solution is associated with a relatively high cost because the Ringer's solution is more expensive.

#### Object of the Invention

The object of the present invention is to provide a method for processing intra- or postoperative blood loss for autotransfusion, making it possible to obtain a highly pure concentrate by using only small volumes of a dilution solution. This object is achieved with a method for processing a cell suspension for autotransfusion comprising the steps of centrifuging the suspension in a separation unit, removing the concentrated cells from the separation unit, and diluting the concentrated cells with a physiological solution.

Another object of the present invention is to make available

an apparatus for carrying out the method of processing intra- or postoperative blood loss for autotransfusion. This object is achieved with a device for processing red blood cell suspensions for autotransfusion comprising one or more separation units disposed in a centrifuge, wherein the separation unit has a suspension inlet line, a red blood cell outlet line and a waste line, wherein the red blood cell outlet line is connected to a diluting device. According to the invention, a red blood cell suspension enters the separation unit through the inlet line and is concentrated in the separation unit. The concentrated red blood cells are then removed through the red blood cell outlet line where they are diluted with a physiologic solution.

The method of processing a cell suspension for autotransfusion according to the present invention, especially for continuous processing of intra- or postoperative blood loss to yield an RBC concentrate for the purpose of returning it to the patient, is based on the fact that autotransfusion is performed without rinsing or washing the concentrated cells again. With the method according to the present invention, certain cells of the prepared cell suspension, mainly the red blood cells, are concentrated by centrifuging in a separation unit and are removed from the separation unit without washing or rinsing the concentrated cells in the separation unit. Surprisingly, it has been found that separation is not only much faster but is also more effective inasmuch as the cell concentrate obtained, in particular the RBC concentrate, has a greater purity, i.e., less contamination with white blood cells.

Only small volumes of a dilution solution are necessary to dilute the cell concentrate thus obtained. Therefore, using Ringer's solution, which is tolerated much better by the patient than saline solution, is not associated with much higher costs. Instead of Ringer's solution, however, the cell concentrate may also be diluted with stock solutions for blood cells, etc.

It is also advantageous that the desired hematocrit of the end product can be adjusted freely by selecting the dilution ratio. This also avoids large volumes of waste contaminated with blood components. Extraction of red blood cells is very efficient because there is no cell loss in a washing operation. The plasma components of the blood can be collected undiluted for further use.

The apparatus for carrying out the method according to the present invention has a simplified design inasmuch as no separate inlet line for a wash solution is needed on the separation unit. Thus, the separation unit, which is preferably designed as a disposable unit, may be manufactured inexpensively. The cell concentrate is preferably diluted immediately after removal from the separation unit. In a preferred embodiment of the apparatus according to the present invention, the device for dilution of the cell fraction removed from the separation unit has a container to accommodate the physiological dilution solution and an inlet line leading away from the container and opening into the outlet line for the concentrated cell fraction. The mixing point where the inlet line for the dilution solution opens into the outlet line for the cell concentrate is preferably located upstream from the delivery pump by means of which the cell fraction is removed from the separation unit. This minimizes hemolysis effects due to high cell concentration and shearing forces. To be able to freely select the hematocrit of the end product, the dilution device has a control unit which can adjust the delivery rate of the pump for supplying the dilution solution. The present invention is explained in greater detail below on the basis of one embodiment with reference to the drawings.

### Brief Description of the Figures

Figure 1: a simplified schematic diagram of an embodiment of the apparatus according to the present invention for processing intra- or postoperative blood loss for autotransfusion;

Figure 2: a simplified schematic diagram of the separation unit of the apparatus for carrying out the process from Figure 1.

### Detailed Description of the Preferred Embodiment

The apparatus includes a centrifuge 1 with a centrifuge chamber 2 designed as a disposable unit which is inserted into the centrifuge. These parts are only alluded to in Figure 1.

Centrifuge chamber 2 has an annular channel 3 (Figure 2). Provided on the inside of the narrow end of the annular channel is a connection 4 to which is connected an inlet line 5 for supplying the cell suspension to be processed, which comes from a container 6 holding a patient's blood mixture collected during or after surgery. An occluding blood pump 7 is connected to inlet line 5.

Provided on the outside of the end of the annular channel there is a connection 8 to which is connected a first outlet line 9 for the concentrated cell fraction, i.e., the RBC concentrate (RBC) leading to a collecting tank 10. An occluding concentrate pump 11 is connected to the first outlet line 9.

A second outlet line 13 for unwanted components (plasma, PLS) leading to another collecting tank 12 is connected to a connection 14 of the separation chamber provided on the inside of annular channel 3.

During operation of the apparatus, the blood mixture to be processed is delivered by blood pump 7 to rotating separation chamber 2, in whose annular channel 3 the whole blood is separated under the effect of centrifugal force, with the red blood cells settling on the outside of the annular channel and being removed continuously from the separation chamber by concentrate pump 11 through the first outlet line 9 and collected

in tank 10. However, unneeded components (tissue fluid/plasma) of the blood mixture are removed continuously through the second outlet line 13 and collected in tank 12.

The apparatus according to the present invention also has a device 22 for diluting the RBC concentrate removed through the first outlet line 9. Dilution device 22 includes a tank 15 to hold the dilution solution, preferably Ringer's solution, with an inlet line 16 leading away from it and opening into the first outlet line 9 upstream from concentrate pump 11 at a mixing point 23. An occluding delivery pump 17 connected to inlet line 16 is also connected to a central control unit 19 by a control line 18. Control unit 19 is also connected to blood pump 7 and concentrate pump 11 by additional control lines 20, 21. The delivery rates of pumps 7, 11, 17 can be set by the control unit. The desired hematocrit of the RBC concentrate to be returned to the patient can be preset by appropriate adjustment of the delivery rate of pump 17 or pump 11.

The blood mixture is separated to a hematocrit of 60 to 98, preferably 85, in separation chamber 2, which may be designed in the shape of a ring or a spiral.

The following table shows the plasma and WBC elimination rates that can be achieved with the method according to the present invention at a hematocrit of the blood of 20% and a hematocrit of the RBC concentrate of 70%, 80% and 90%.

Hct (blood) (%)	Hct (RBC concentrate) (%)	Plasma elimination (%)	WBC elimination (%)
20	70	89	approx. 80
20	80	94	approx. 90
20	90	97	> 90